Guideline on the Maintenance of Indoor Air Quality

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ABSTRACT: This guideline is a compilation of data and information developed to help in the maintenance of indoor air quality in buildings occupied by Digital.

APPLICABILITY: This is a guideline that offers options to assist in the maintenance of air quality in buildings occupied by Digital. Should other methods be available that prove to be equally or more effective, they should be considered as viable alternatives.

STATUS: APPROVED 21-Jan-1992; use VTX SMC for current status.

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CONTENTS

EXECUTIVE SUMMARY v

1 OBJECTIVE 1
1.1 SCOPE 1
1.2 APPLICATION 1

2 BACKGROUND 1
2.1 COMPLAINT MECHANISM 2
2.2 INDOOR AIR QUALITY MAINTENANCE 2
2.3 OPEN OFFICE ENVIRONMENT 2
2.4 DEFINITION OF ACCEPTABLE INDOOR AIR QUALITY 2
2.5 STUDIES OF CAUSATION 3
2.6 DIGITAL'S CLEAN AIR POLICY 3

3 GUIDELINE 4
3.1 GUIDELINE FOR EXISTING BUILDINGS OCCUPIED BY DIGITAL 4
3.2 GUIDELINE FOR BUILDINGS NEW TO DIGITAL OCCUPANCY 4
3.3 DEFINITION OF RECOMMENDED INDOOR AIR QUALITY PARAMETERS FOR THE GENERAL OFFICE ENVIRONMENT 5
3.3.1 Chemical and Physical Parameters 5
3.3.2 Biological Parameters 6
3.3.3 Legionnaires Disease Bacteria (LDB) 6

4 ACTIONS AND RESPONSIBILITIES 7
4.1 RESPONSE TO INDOOR AIR QUALITY COMPLAINTS 7
4.2 ADDITIONAL ASSISTANCE 7
4.3 ENVIRONMENTAL HEALTH AND SAFETY RESPONSIBILITIES 7
4.4 FACILITIES AND PROPERTY ORGANIZATION RESPONSIBILITIES 8
4.5 HEALTH SERVICES RESPONSIBILITIES 9

5 RECOMMENDED PREVENTIVE MEASURES 10
5.1 ENVIRONMENTAL HEALTH AND SAFETY INVOLVEMENT 10
5.2 MAINTENANCE AND OPERATION 11
5.3 DAMPNESS, HUMIDIFICATION, AND MOISTURE ABSORBING MATERIAL 11
5.4 VENTILATION AND EXHAUST SYSTEM DESIGN 12
5.5 CLEANLINESS 12
5.6 ENERGY CONSERVATION 12
5.7 MORNING BUILDING STARTUP 12
5.8 EMPLOYEE PROTECTION 13

Appendix A AIR CONDITIONING SYSTEMS EFFECTS ON INDOOR AIR QUALITY 15

Appendix B DETERMINATION OF THE OUTSIDE AIR COMPONENT IN THE VENTILATION SYSTEM 17

Appendix C MEASUREMENTS OF AIRBORNE CONTAMINANTS 21

Appendix D GUIDELINE FOR THE CONTROL OF LEGIONNAIRES' DISEASE BACTERIA IN COOLING SYSTEMS 23

D.1 PURPOSE 23

D.2 BACKGROUND 23
D.2.1 COOLING TOWERS AND EVAPORATIVE CONDENSERS 23
D.2.2 SUGGESTED COURSE OF ACTION 23

D.3 GUIDELINE 24
D.3.1 MONTHLY INSPECTION 24
D.3.2 DRAINING AND CLEANING 24
D.3.3 CHEMICAL BIOCIDE TREATMENT 24
D.3.4 OZONATION 24
D.3.5 ANALYSIS OF MICROBIOLOGIC CONTENT OF COOLING WATER 25
D.3.6 PROCESS DOCUMENTATION 25
D.3.7 LEGIONNAIRES' DISEASE BACTERIA SAMPLING AND CULTURING RECOMMENDATIONS 25
D.3.8 EMPLOYEE PROTECTION 26

Appendix E GENERAL INDOOR AIR QUALITY SURVEY QUESTIONNAIRES 27

Appendix F REFERENCED DOCUMENTS 35

F.1 Other Digital Documents 35

F.2 Other Documents 35

F.3 Ordering Information 35

FIGURES

1 Typical HVAC System 17

EXECUTIVE SUMMARY

INTRODUCTION

The purpose of this guideline is to:

1. Create an increased awareness of the issues surrounding indoor air quality complaints which may adversely effect health, safety, and productivity.
2. Aid in the anticipation and avoidance of the conditions from which indoor air quality complaints may result.
3. Aid in the recognition and evaluation of the causes of indoor air quality complaints and in attempts at their remediation.
4. Identify resources available to aid in the remediation of indoor air quality complaints.

Much of what is being suggested should not be new but already be part of the existing site programs and activities.

GUIDELINE

This document provides *alternatives* to assist in the maintenance of a safe working environment. Its purpose is to assist site personnel (Environmental Health and Safety, facilities or property organization, and Health Services) to recognize the conditions which are potential precursors to indoor air quality issues. The guideline assists in the response to these conditions before there is a risk to health, safety, and productivity. It also provides a proactive process by which indoor air quality parameters and the conditions inside and/or outside the facility that may affect indoor air quality can be monitored on a regular basis.

It is not the intent of this guideline to require the blanket modification of existing Digital occupied buildings to meet minimum heating, ventilating and air conditioning (HVAC) system guidelines as discussed in this document or in current government, consensus, and/or industry standards or guidelines.

SUMMARY

This document provides background information on how to respond to indoor air quality complaints and the conditions and constituents that cause or signal these complaints. This background information allows the reader to begin to understand why the lack of adequate indoor air quality can be a problem, as well as why and how the problem can be different in each facility. The guideline summarizes recommended parameters and conditions for the maintenance of indoor air quality and the process by which they can be monitored and maintained.

The document identifies additional resources which are available. They can be of assistance in the event that a facility is found to be experiencing indoor air quality issues. There are recommendations that relate to building design, maintenance, and operation that will aid in avoiding the occurrence of indoor air quality complaints. The document also contains several appendices with information that will also assist in this effort.

1 OBJECTIVE

The purpose of this guideline is to help in the maintenance of air quality in buildings occupied by Digital. This guideline is a compilation of data and information that has been developed through a cooperative effort involving professionals in the areas of Environmental Health and Safety, design and facilities, and Health Services to assist in providing Digital employees and their visitors a safe working environment, free from recognized hazards.

1.1 SCOPE

This is a GUIDELINE and as such, offers options to assist in the maintenance of air quality in buildings occupied by Digital. Should other methods be available that may prove to be equally or more effective, they should be considered as viable alternatives.

It is not the intent of this guideline to require the blanket modification of existing Digital occupied buildings to meet minimum heating ventilating and air conditioning (HVAC) system guidelines as discussed in this document or in current government, consensus, or industry standards or guidelines.

Much of what is being suggested should be part of existing site programs and activities.

Should indoor air quality complaints occur, existing building systems should be reviewed and maximized by applying corresponding portions of this guideline as well as good engineering practice.

Only after a review and optimization of existing systems and the determination they are not capable of meeting the design intent of the building functionality, should significant modifications and/or cost-effective capital expenditures be considered.

In some cases, there may not be an acceptable modification that will resolve an indoor air quality complaint. A major retrofit of the facility may not be a viable alternative. It may then ultimately be decided that the building does not meet Digital's requirements and seeking alternative space might be in the company's best interest.

1.2 APPLICATION

The primary application of this document is for the maintenance of the indoor air quality in the office environment. Certain of the suggestions may have wider application in the industrial environment.

2 BACKGROUND

Environmental concerns over air pollution typically focus upon the air outside of a building. "Air pollution" can occur within the confines of a building as well. Poor indoor air quality can be attributed to many different sources that may not be easily identified. Some of the terms commonly used to describe *indoor air quality complaints* include *indoor air pollution, tight building syndrome,* and *sick building syndrome.*

2.1 COMPLAINT MECHANISM

One possible mechanism to explain indoor air quality complaints is thought to be the concentration of low levels of contaminants in a relatively enclosed environment.

These conditions may occur due to the inadequate control, dilution, dissipation or removal of contaminants from the inside air and/or contaminant entrainment into the building's outside air supply.

These conditions may result in valid employee discomfort and health complaints such as eye and respiratory tract irritation, headache, drowsiness, fatigue, nausea, and general malaise. These complaints may occur even though there is no readily obvious cause.

Contaminants such as gases, vapors, particles, and micro-organisms are continuously introduced into the indoor environment by the presence and activity of building occupants, the outgassing of the building components and furnishings, the use of chemicals, and from external sources (such as by outside air makeup and infiltration).

When not removed or dissipated through ventilation, these pollutants may concentrate to the level where they may further become an irritant and, if in sufficient concentrations, may adversely affect human health.

There are a wide variety of health effects and potential causes that introduce multiple variables when searching for a solution.

In many situations, a change or modification made to the building environment may result in the disappearance of symptoms without a causative agent actually being identified.

2.2 INDOOR AIR QUALITY MAINTENANCE

The maintenance of acceptable indoor air quality can be accomplished by general ventilation through the proper intake, filtration (as needed), and distribution of outside air into the building; by local exhaust ventilation to control contaminants generated by processes being conducted in the building; and by the proper and ongoing maintenance of these systems.

Proper maintenance and operation of the building heating, ventilating, and air conditioning (HVAC) systems is essential to the prevention of a majority of indoor air quality problems.

2.3 OPEN OFFICE ENVIRONMENT

The open office environment includes partitions that extend from floor level to some height below the ceiling. When using standard diffusers, this arrangement impedes adequate air flow and distribution.

2.4 DEFINITION OF ACCEPTABLE INDOOR AIR QUALITY

Acceptable indoor air quality can be defined as "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction."

2.5 STUDIES OF CAUSATION

Studies have shown the following as the major causes of indoor air quality complaints:

- **Inadequate Ventilation (52%):** such as inadequate outside air, poor air distribution, temperature extremes and environmental differences between areas, misapplied energy conservation measures, and general lack of overall system maintenance.
- **Inside Contamination (17%):** such as off gassing from copy machines, pesticides, boiler additives in humidification systems, cleaning agents, tobacco smoke (*Note: Digital has implemented a Clean Air Policy in the U.S.*) and improper and/or inadequate exhaust of combustion sources and process equipment.
- **Outside Contamination (11%):** such as motor vehicle exhaust, boiler gases, exhaust re-entrainment, construction, and roofing.
- **Biological Contamination (5%):** such as dampness and/or water damage to carpets or furnishings or standing water in ventilation system components.
- **Building Fabric Contamination (3%):** such as off gassing from particle board, carpet glues and adhesives, deterioration of fibrous glass-lined duct work, and solvents from caulking materials.
- **Unknown Cause (12%):** ???????

Drastic building modifications, such as those involving the HVAC system, should not be undertaken until the existing building system is reviewed, its operation optimized, and other potential causes for building-related complaints are eliminated.

Misapplication of energy conservation measures and some energy efficient building designs may bring about conditions that result in the development of indoor air quality complaints. The degree of the application of energy conservation measures must be balanced with the potential needs of the building occupants to ensure that both needs are adequately addressed.

Building-related issues should be addressed quickly to resolve the issue along with maintaining the confidence of the building occupants and good employee relations.

2.6 DIGITAL'S CLEAN AIR POLICY

Digital Equipment Corporation in the U.S. has implemented a Clean Air Policy that controls smoking in the workplace. This removes a significant contributing factor to the building-related complaints.

3 GUIDELINE

3.1 GUIDELINE FOR EXISTING BUILDINGS OCCUPIED BY DIGITAL

Facility and property managers are responsible for implementing a program to ensure that indoor air quality issues are avoided and/or resolved as soon as the problems or their potential existence is recognized. The site or responsible Environmental Health and Safety Group should also be involved in the program implementation and management.

This program should include, but not be limited to, a written program defining documented regular HVAC inspection and maintenance schedule with concurrent indoor air quality monitoring which should be performed at least quarterly to ensure the maintenance of acceptable levels of ventilation and the control of potential contaminants.

At a minimum, documented air quality monitoring should include: carbon dioxide concentration, temperature, and relative humidity. The building will need to be monitored at a sufficient number of locations to ensure representative sampling of the occupied space. These should include sampling locations on each floor in open areas and within enclosed offices. For reference, a set of measurements should be taken outside of the building. This information may be especially important when comparing carbon dioxide concentrations and relative humidity.

The potential presence and concentration levels of additional constituents of indoor air in buildings will vary according to the types of operations being performed and the controls in place. The concentrations of these materials should also be monitored. The recommended levels of ventilation and potential contaminants for the majority of spaces are noted below.

3.2 GUIDELINE FOR BUILDINGS NEW TO DIGITAL OCCUPANCY

Before an agreement is made to occupy a newly constructed or leased building, a review should confirm that the building meets or exceeds the following minimum conditions. This should be confirmed by the responsible business, Corporate Design and Facilities, or facilities or property organization. The site or responsible Environmental Health and Safety Group should also be involved to assist in the program implementation and management.

The operational characteristics of the ventilation system should allow the building to meet the applicable local and/or country codes and consensus standards, such as the ASHRAE Standard 62-1987, *Ventilation for Acceptable Indoor Air Quality*.

The configuration of the building air supply should be such that the potential for contaminant and/or exhaust re-entrainment is minimal. Intakes should be placed so as not to increase the potential for re-entrainment from building processes, sanitary exhausts, power and boiler room exhaust, and contaminants.

The building materials and furnishings should be reviewed and selected with characteristics that minimize the generation of potentially hazardous materials into the work environment (such as low or no solvent adhesives, latex based paints, and so forth).

The HVAC system(s) should function at operating temperatures for a period of time prior to beneficial occupancy in a newly fit-up or completed building. This helps to purge the odors associated with new paint, carpet, furniture, and other newly installed building finish and furnishings.

Where possible, the definition of minimum indoor air quality requirements should be included as part of the lease specifications.

3.3 DEFINITION OF RECOMMENDED INDOOR AIR QUALITY PARAMETERS FOR THE GENERAL OFFICE ENVIRONMENT

These values are offered as reference. They are generally thought to represent an environment having acceptable indoor air quality. They should not be considered to indicate a fine line between an acceptable and unacceptable condition. It is possible that if the parameters are not attained there may be, by definition, acceptable indoor air quality. It is also possible that these parameters might be attained and there might still not be, by definition, acceptable indoor air quality.

These recommendations should complement the current Digital Property Development Performance Guidelines, *Design and Development of the Work Environment* where appropriate. Also refer to subhead 1.2 of this document.

Applicable country and/or local codes and standards, where they are more stringent, should take precedence.

3.3.1 Chemical and Physical Parameters

These are among the parameters usually evaluated in response to a vast majority of indoor air quality complaints. They can also be selectively included as part of routine monitoring, maintenance, and/or inspection. Suggested building and equipment characteristics are also included.

Outside Air	
20 cfm/person	For buildings where moderate smoking is permitted. Does not include designated smoking areas.
15 cfm/person	For buildings where smoking is not permitted. Also see ASHRAE 62-1989 Section 6.1.3.1 Multiple Spaces
Temperature	
Winter	68°F (20°C) minimum
Summer	78°F (25.6°C) maximum
Air Movement	
20-50 ft/min	In the work area, at desk level.
Air Filtration Efficiency	
Greater than 50% efficient	For new buildings. For existing buildings, to increase the filter efficiency, air-handling equipment must be evaluated for the ability to handle any required retrofit and any additional system resistance.

Contaminants	
Carbon dioxide	700 ppm This is an indicator of ventilation system efficiency and the adequacy of outside air introduction. Complaints can be expected to begin in the range of 700 - 1000 ppm. Periods during which peak concentrations can be expected: 10 - 11 A.M. (1000 - 1100 hours) and 2 - 3 P.M. (1400 - 1500 hours). This assumes an outside background carbon dioxide concentration of 350 - 400 ppm. A higher natural background carbon dioxide concentration must be considered and accounted for when using the concentration of carbon dioxide as a diagnostic tool.
Formaldehyde	Less than 0.1 ppm
Carbon monoxide	Less than 10 ppm
Other Potential Contaminants Recommended Levels	
Nonindustrial office environments for contaminant and odor control	Less than 0.1 X applicable occupational exposure limit

3.3.2 Biological Parameters

Complaints that may result from bioaerosol contamination account for few of the actual building-related complaints. Bioaerosols are routinely present in the day-to-day environment. The main concern is that factors in the indoor environment do not significantly amplify (increase) normal outdoor levels. Depending on the species involved, the acceptable degree of amplification may be as much as 100 to 200 times increase when comparing indoors to outdoors.

The first response should be the "visual remediation" of areas suspected of being the source of the complaint. This remediation may involve the drying, cleaning, and disinfection of air-handling equipment and the removal of wet and/or water-damaged building materials and furnishings. Refer to details within this document.

Bioaerosol monitoring should not be undertaken as a routine activity. Such sampling should be conducted only if after visual remediation and other system reviews have taken place, there is still an issue that points to the potential for a bioaerosol being the causative agent and the source has not been identified.

Should bioaerosol monitoring be deemed necessary, it should be performed by or under the supervision of a person trained in the applicable sampling techniques and capable of properly interpreting the data. Information on capable consultants can be obtained from Area or Corporate Environmental Health and Safety, Corporate Design and Facilities, and Corporate and/or Area Health Services.

3.3.3 Legionnaires Disease Bacteria (LDB)

LDB is normally present in nature, principally in water and to a lesser degree in soil.

Routine culturing for LDB without a clearly defined outbreak of the disease is not recommended. There is difficulty in culturing and interpretation of the results that may lead to improper conclusions being drawn and the raising of unnecessary concerns.

The most prudent course of action is to keep systems as clean as practical through a documented cleaning and maintenance program for cooling towers and similar equipment. Refer to Appendix D for additional details.

4 ACTIONS AND RESPONSIBILITIES

4.1 RESPONSE TO INDOOR AIR QUALITY COMPLAINTS

When there are indoor air quality complaints, even if the building parameters coincide with the stated guidelines, remedial action is required. It is essential that there be a cooperative effort involving the site or responsible Facilities or Property Organization, Environmental Health and Safety Group, and Health Services to ensure that the issue is dealt with quickly and responsibly. The following process should be undertaken simultaneously by the responsible groups, while keeping in close communication.

Environmental Health and Safety should investigate the areas of complaints and/or out of tolerance conditions for potential contaminant sources and provide assistance as outlined under subhead 4.3.

Facilities and Property Organization should check the HVAC system to determine if it is operating efficiently, within its design parameters, and is not a potential contaminant source as outlined under subhead 4.4.

Health Services should provide affected employees with medical support services as outlined under subhead 4.5.

4.2 ADDITIONAL ASSISTANCE

Should initial remedial efforts fail to resolve the issue, Area or Corporate Environmental Health and Safety, Corporate Design and Facilities, and Corporate and/or Area Health Services are among the available resources for additional information and support relating to:

Designing and conducting studies that evaluate the cause(s) of indoor air pollution and resulting employee health complaints.

Methodologies for characterizing indoor air for the potential presence of chemical and biological contaminants.

The current technologies for maintaining acceptable indoor air quality.

Liaison with outside consultants and government agencies.

Support and assistance in identifying and hiring outside consultants.

4.3 ENVIRONMENTAL HEALTH AND SAFETY RESPONSIBILITIES

Environmental Health and Safety should provide support and work with Health Services and the facilities or property organization in the definition of potential causation for the building-related complaints. This support may include the following:

Review and monitor areas of employee complaints for potential contaminant sources such as:

- Laser printers and copiers may generate ozone which is an irritant. This potential is increased if this equipment is not properly maintained (such as the ozone filter not changed in a timely manner) and/or if it is located in an enclosed area with minimal ventilation.
- Potted plants and the resulting moisture can be sources of microbiological growth, allergens, as well as potentially increasing the humidity in their vicinity.
- Signs of water damage (wet ceiling tiles, stained carpets or walls) that can be sources of mold and other biological growth.
- New office furnishings such as carpeting, wall partitions, and furniture are a potential source of chemical irritants that include but are not confined to formaldehyde and a variety of volatile organic compounds (VOC).
- Significant amounts and uses of items such as carbonless forms, correction fluids, cleaning agents, air fresheners, and so forth are potential sources of VOCs.

Ensure that there have not been any unauthorized modifications of the air-handling system such as the blocking and/or redirecting airflow from diffusers.

Interview employees experiencing discomfort in order to attempt to identify the cause of the complaints and evaluate if any operations or work processes could be contributing or generating contaminants. This interview must be done quickly to ensure it is possible to identify conditions out of the ordinary or different that may be occurring on site or in the vicinity on the day in question.

Review and monitor contaminants potentially coming from nearby sources such as manufacturing, engineering, or construction areas that may require additional degrees of control such as local exhaust and/or dilution ventilation. Construction activities that may be disruptive such as by the generation of dust and/or odors into occupied spaces should be scheduled, where feasible, at times so as not to adversely effect the day-to-day activities of the facility.

Observe the location, design, and condition of outdoor air intakes for actual evidence or the potential for contamination and/or entrainment from adjacent neighboring buildings, operations, or activities.

Inspect and test existing local exhaust ventilation to ensure that its design and airflow are adequate for the particular operation being performed.

4.4 FACILITIES AND PROPERTY ORGANIZATION RESPONSIBILITIES

The following factors should be included in the review and maximization of the building HVAC systems. Deficiencies found to exist should be corrected as part of the review. The items are listed in general order of priority.

Variable air volume devices (VAV) should be inspected to ensure that they are functional and operating according to specification. A recommended minimum airflow volume setting of supply air being introduced into the space should be 15% of the full cooling design capacity for that VAV terminal device.

The presence of standing or stagnant water such as in air-handler condensate drip pans that do not completely drain is not acceptable. Drip pans should be releveled or modified to maintain proper drainage. The routine ongoing use of biocides in the airstream should not be permitted. At a minimum, there should be periodic cleaning of coils, drip pans, traps, and other potentially wetted areas before and after the cooling season. The use of biocides to clean during maintenance should be done while the system is not functioning and the space that it serves is not occupied. The system should be run for a sufficient time to purge it of residual biocide and associated odors after cleaning is complete.

Temperature and/or relative humidity should be monitored over time to ascertain if temperature and humidity are within the range of the HVAC operational parameters. This can be done with a sling psychrometer and a thermometer or a more elaborate device capable of monitoring over a period of hours or days. Also, the air-conditioning system capacity and the amount of electronic equipment in complaint areas should be reviewed to determine if sufficient air-conditioning exists to deal with the resulting heat load if temperature extremes are experienced.

Air inlets and exhausts should be checked for the potential of re-entrainment into the building HVAC system of building exhaust (process, sanitary, and/or from the heating or power plant) or contaminated outside air from other sources. Under controlled situations and in conjunction with Environmental Health and Safety, smoke candles can be used to define and illustrate air movement on the roof. This smoke can visually show the potential for re-entrainment into the building air supply from exhaust sources (exhaust fans, plumbing vents, boiler flues, cooling tower plumes, and so forth). Special attention should be given to the effects of wind at the edges of buildings. (The use of a smoke candle generates a large plume of smoke that can cause some alarm. Extreme care must be used in the application of this technique.)

The entire system should be inspected from the point where the air enters the building to the point where it is exhausted both on the outside and inside of equipment. Accumulations of dust, dirt, and other debris should be removed.

Air-handling unit filter racking systems should be tight and the filters secure. If the racks and/or filters are loose, air will short circuit the filters and pass untreated into the building system. Filters should be of the proper type (and if the system can accommodate them, have an efficiency greater than 50%). They should be changed according to a written replacement schedule as recommended by the manufacturer and then validated through experience in the particular facility.

Severely wetted and/or contaminated materials should be removed where possible or disinfected if removal is not a viable alternative. This effort should be coordinated with Environmental Health and Safety to ensure that the proper precautions are taken.

4.5 HEALTH SERVICES RESPONSIBILITIES

Health Services should provide or ensure that employees receive the required medical care as well as working with Environmental Health and Safety and the facilities or property organization in the definition of the potential causative agent for the complaint including:

Interview and examine the affected employee in order, if possible, to make a clinical diagnosis in each case. This understanding will assist in the medical treatment. It may also provide assistance to Environmental Health and Safety and the facilities or property

organization to assist in the definition and eventual alleviation of the physical cause by helping to point out some needed modification to the building or a component system.

Indoor air quality complaints may be generally defined in one of two ways:

1. **Sick-Building Syndrome:** This complaint includes nonspecific symptoms such as mucous membrane irritation, headache, and fatigue. It may be caused by any one or a combination of a multitude of low levels of many constituents normally found in the indoor environment. Abnormalities in physical symptoms and/or laboratory tests will not usually occur in persons with these symptoms. A significant portion of the population may be affected. There may be a localized group affected or if personal sensitivity is involved only one person affected. These types of complaints can usually be controlled by attention to the building ventilation system.
2. **Building-Related Diseases:** This complaint includes infections such as legionellosis, and the hypersensitivity diseases. Hypersensitivity diseases involve the sensitization to saprophytic bioaerosols, including humidifier fever and hypersensitivity pneumonitis (HP), asthma, and allergic rhinitis. HP is by far the most serious of the building related illnesses since it involves individual sensitization to a specific bioaerosol. One case may constitute an outbreak.

The symptoms that are associated with building-related complaints are usually general and nonspecific. While the workplace evaluation is being conducted, the employee should be encouraged to visit their personal physician to determine if there is an underlying organic cause for the symptoms being experienced.

Early involvement of the Site Health Services Consultant and their communication with the employee's personal physician is encouraged.

Be available to discuss the issue with the affected employee(s) and an employee relations representative should the situation dictate.

Employees with symptoms or complaints should be interviewed and examined as medically appropriate by Digital Health Services, if available, or by its designated examiner as part of the attempt to resolve what building-related issues may exist.

Consult with Digital Corporate or Area Health Services when complaints are widespread, difficult to resolve, or if there are any documented cases of building-related disease.

5 RECOMMENDED PREVENTIVE MEASURES

This guideline helps provide a safe environment in buildings occupied by Digital Equipment Corporation. The following recommendations are offered to assist in the maintenance of acceptable indoor air quality.

5.1 ENVIRONMENTAL HEALTH AND SAFETY INVOLVEMENT

There should be close coordination with site Environmental Health and Safety to ensure that environmental and permitting concerns are adequately addressed.

Potential issues may involve, but are not be limited to:

- Permitting of stacks venting process exhaust
- Treatment and disposal of cooling tower blowdown

- Ensuring restricted chemicals (such as chromium compounds such as corrosion preventatives for cooling towers) are not used

5.2 MAINTENANCE AND OPERATION

HVAC systems should be maintained clean and in proper operating condition at all times.

A part of any maintenance program should be routine verification that the systems are operating at design conditions. Refer to the guidelines under main head 3, for suggestions of minimum system maintenance.

Control of items hanging from the ceilings that could impede air movement (such as flags, plants, and so forth). Nothing should be hung from sprinkler heads.

5.3 DAMPNESS, HUMIDIFICATION, AND MOISTURE ABSORBING MATERIAL

After floods, water leaks, or fire sprinkler discharge, any water-damaged materials should be routinely examined for the development of mold. The only manner of ensuring no mold will grow is to remove and dispose of the damaged materials.

The use of humidifiers should be discouraged in all but process or manufacturing areas. There may be exceptions, including particular regional climatic conditions that will require general area humidification. Regardless of the justification or application, if not properly operated and maintained, any humidification system can create conditions conducive to growth of microorganisms and allergens.

Areas requiring humidification due to process or manufacturing requirements should be carefully designed and the equipment well maintained. Evaporative or infrared type humidifiers are not usually recommended. Self-contained steam-generating type humidifiers are less apt to be a problem. Regardless of the application, proper equipment maintenance and cleanliness is essential.

Chemical treatment injection systems that add amines and/or other potentially irritating chemicals to boilers that supply steam to humidification systems should be inspected at least weekly as part of a documented maintenance program. This inspection ensures that the system is operating properly and the manufacturer-recommended quantities of chemicals is added.

- It may be possible to avoid or minimize the use of boiler treatment chemicals. If the capability exists, the use of water that is alternately referred to as 0.1 megohm, 2 bed, or reverse osmosis (RO), with the addition of sodium sulfite as an anti-oxidant (approximately 1%) is suggested.
- The boiler should be totally flushed after the seasonal cleaning to ensure there are no residual cleaning chemicals.

Of special concern is the use of duct-mounted type of humidifiers used in acoustically lined ductwork in air-conditioning systems.

The use of moisture-absorbing material, such as certain types of insulation, inside air-conditioning ductwork is not recommended.

Damaged duct-lining material should be repaired. It can accumulate dirt and moisture as well as possibly further degrading, generating additional airborne contaminants and odors. This material provides a site for the growth of microorganisms that, in sufficient quantities, can cause illness.

5.4 VENTILATION AND EXHAUST SYSTEM DESIGN

When installing or inspecting outside air intakes and/or exhaust systems, be aware of the proximity of existing intakes and exhaust devices.

Intakes and exhausts should be located as far apart as possible. They should be properly designed to reduce the potential for contaminant re-entrainment.

Exhaust stacks should be above the air inlets and be of the vertical discharge type. Mushroom cap devices for exhausts are not recommended.

New installations and modifications to existing systems should take into account and attempt to avoid potential effect on and/or by the location of cooling towers, adjacent buildings and other sources of contaminants.

5.5 CLEANLINESS

There should be proper cleaning of occupied spaces, including kitchen and cafeteria areas, to eliminate potential concentrations of contaminants and dust. This cleaning is essential in the maintenance of acceptable indoor air quality. Be especially aware of break areas and high traffic areas for spilled coffee and/or food on carpets and wall or partition fabric. Cleaning materials and solvents should be chosen carefully so as not to contribute to potential indoor air quality issues.

5.6 ENERGY CONSERVATION

Energy efficiency measures such as duty cycling of air-conditioning systems or the improper operation of economizers are detrimental to good indoor air quality. There are more efficient ways to conserve energy. Consult the Digital Property Development Performance Guidelines, *Design and Development of the Work Environment.*

Care should be exercised when implementing these type of measures to ensure that proper ventilation is not inhibited.

5.7 MORNING BUILDING STARTUP

Morning warm-up and cool-down cycles routinely keep outside air dampers closed until the building is at temperature.

Initialize these cycles earlier (about 15 minutes). The temperature control will open the dampers 15 minutes earlier and purge the building of occupant-generated contamination remaining from the previous day. This purge reduces the potential for the perception of stuffiness when building occupants begin to arrive in the morning.

The effectiveness of this technique can be monitored by measuring the concentration of carbon dioxide level before the building is occupied in the morning. It should be roughly equal to that of the outside air. If this is not the case, the initialization of the warm-up or cool-down cycle should be done earlier until the desired effect is obtained.

5.8 EMPLOYEE PROTECTION

Employees performing work on HVAC systems must be protected from possible chemical or biological hazards.

Potential exposures may result from proximity to the unit (that is, downwind of an exhaust stack) or from the work being performed (that is, dust generated during filter changes).

Where necessary, appropriate engineering controls (ventilation), training (hazard awareness), and personal protective equipment (gloves, face shield, respirator) should be incorporated into the maintenance program.

APPENDIX A AIR CONDITIONING SYSTEMS EFFECTS ON INDOOR AIR QUALITY

Air-conditioning systems play a major role in maintaining the quality of the work environment and therefore the productivity of the people who work there. An air-conditioning system distributes fresh outside air to the work space as well as maintains comfort conditions. Unfortunately, these two functions can conflict with each other. This conflict has led to a vast number of indoor air quality complaints and problems. The purpose of this appendix is to highlight one common situation that can lead to complaints of poor indoor air quality even though the air-conditioning systems are properly installed and maintained.

Air-conditioning systems are designed to provide a specific amount of cooling to offset the heat generated by office equipment (such as personal computers, terminals, and typewriters), people, lights, and sunlight. Unfortunately, the amount of cooling required in any specific area is constantly changing. More cooling may be required in the afternoon due to the heat of the afternoon sun. A specific conference room can have varying numbers of occupants and may only be occupied intermittently. All, some, or none of the office equipment may be on at any given time. Therefore, air-conditioning systems need to be dynamic systems.

The fundamental principle in air-conditioning can be summarized in the following equation.

$$\text{Amount of Heat to be Removed} = \text{Amount of Cool Air Supplied to Space} \times \left[\text{Space Temperature} - \text{Temp. Air Entering Space}\right] \times \text{Constant}$$

The desired room temperature is not truly adjustable. Frequent and significant changes in room temperature are uncomfortable to people. The only two variables that can be adjusted are the amount and temperature of cool air supplied to the space.

Prior to the energy crisis of the early 1970s, the accepted method of manipulating this relationship to accommodate dynamic air-conditioning loads was to keep the amount of air supplied to the space constant. This constant air volume (CAV) was continuously cooled down to the lowest temperature to meet the peak cooling loads. The air was then warmed up, as necessary, to maintain the space at the design temperature whenever the air-conditioning requirements were less than maximum. The benefit of a CAV system is good temperature control and an assurance that outside air is being continually and properly distributed throughout the buildings. These CAV systems were similar to driving a car with one foot on the accelerator and one on the brake, you get where you want to go but not very efficiently.

The more modern solution to the energy intensive CAV system is to continuously cool the air leaving the diffuser to the coolest temperature required to meet the maximum cooling requirements and vary the volume of air being supplied to the space. These variable air volume (VAV) systems provide excellent temperature control and excellent energy efficiency. Unfortunately, the reduction in the volume of air being supplied to the space can also reduce the amount of outside air being supplied to the space. The reduction of airflow in the space can also cause a feeling of stuffiness due to the lack of air movement in the space. The poor distribution of fresh air and the lack of air movement are frequent causes of indoor air complaints.

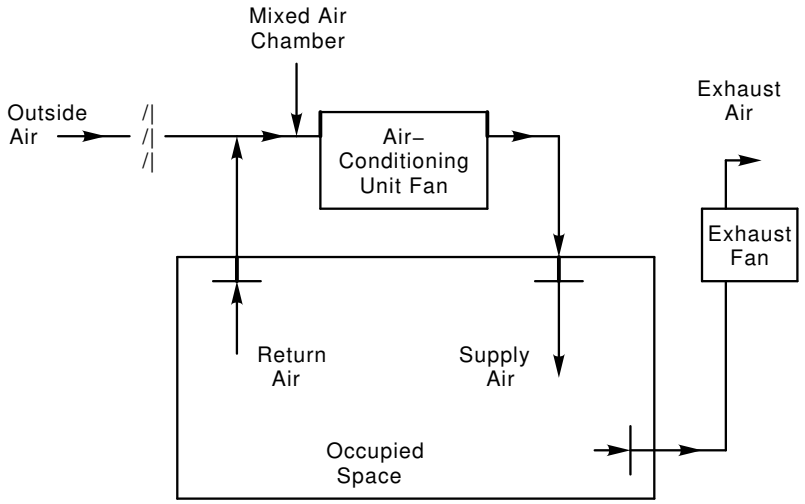
Most VAV systems, when properly designed and operated, usually do not result in indoor air quality complaints. To avoid any potential for problems, current air conditioning system designers use a hybrid of the CAV and VAV systems which are energy efficient as well. These systems use devices called fan-powered induction VAV boxes. These devices contain small fans that keep the amount of air being supplied to the space constant. The amount of cold air necessary for removal of the accumulated heat is still varied. The small fans draw conditioned air from the air-conditioning and warm air (tempered air) from the space in varying amounts to maintain the space at desired conditions while at the same time maintaining good air circulation in the space. These constant-variable air volume (CVAV) systems have proven themselves as a good solution to maintaining good indoor air quality, comfort, and energy efficiency.

APPENDIX B DETERMINATION OF THE OUTSIDE AIR COMPONENT IN THE VENTILATION SYSTEM

The amount of outside air brought into the building can be determined in several ways, and can be accomplished by direct measurement as well as by the use of temperature and/or tracer measurements.

Direct measurement of the magnitude of the outside air component being introduced through each building air-conditioning unit can be done using a velometer, Pitot tube, or other available air velocity measuring instrument. The air volume in cubic feet per minute (CFM) is then calculated from the air velocity measurements and the diameter of the duct. Use of this technique requires experience to ensure reasonable accuracy of the measurements due to the potential for turbulent airflow patterns inside air-conditioning equipment. See Figure 1.

Figure 1: Typical HVAC System



Temperature can be used to calculate the percentage (%) of outside air being introduced into the space. This calculation is done by measuring temperatures of the outside air, return air from the space or building, and the mixture of the two airstreams.

$$\% \text{ Outside Air} = \frac{\text{Return Air Temp.} - \text{Mixed Air Temp.}}{\text{Return Air Temp.} - \text{Outside Air Temp.}} \times 100$$

where: Mixed air temperature should be measured in the air–conditioning unit's mixed air section.

Return air temperature is measured in the inside space or in the duct removing air from the room.

The measurement of the carbon dioxide concentration as a tracer can be used to calculate the percentage of outside air being introduced into a building. This measurements is done by knowing or measuring the system design air volume, and then by measuring carbon dioxide levels in the outside air, the return air in or leaving the occupied space, and in the mixed air before it is returned to the space.

This measurement is best accomplished with the building unoccupied. During the time required to take the measurement, there is assumed to be a steady state concentration and uniformly mixed volume of carbon dioxide.

$$Q2 = \frac{\text{Concentration Mixed Air} - \text{Concentration Background}}{\text{Concentration Return Air} - \text{Concentration Background}} \times Q3$$

$$Q1 = Q3 - Q2$$

$$\% \text{ Outside Air} = \frac{Q1}{Q3} \times 100$$

where[1]:

The outside background concentration is measured in the outside inlet before the air-conditioning unit mixing chamber or outside of the building.
The return air (Return) concentration is measured in the return duct before the mixing chamber or in the duct discharging outdoors.
The mixed air (Mixed) concentration is measured in the mixing chamber air after the mixing point or in the inlet to the room.
Q1 is the volume of outside air.
Q2 is the volume of recirculated air.
Q3 is the total system air volume, including that which is recirculated. This value can either be determined by design fan characteristics or direct measurement.

[1] Gothe,C-J, Bjurstrom,R., Anker,K.:A Simple Method of Estimating Air Recirculation in Ventilation Systems. AIHA Journal. 49(2):66-69 (1988)

The use of tracer gas analysis to determine the outside air component in a building ventilation system is complex and not for general use. These studies involve the use of tracer gases such as sulfur hexafluoride (SF_6) that are inert, nontoxic, odorless, not normally present in the area being tested, and easily measured with little chance for interference.

The accuracy and value of tracer gas methods is dependent on technique and experimental design. The measurement equipment is relatively expensive when compared against the potential for its long-term use. If it is necessary to resort to the use of these methods, a qualified consultant be hired to conduct the testing. This consultant should assure that the resulting data is clear and understandable.

APPENDIX C MEASUREMENTS OF AIRBORNE CONTAMINANTS

This appendix refers to examples of available U.S. and Canadian equipment and its approximate pricing. Depending on the geographic location, this equipment, or equivalents, may be available.

Carbon dioxide may be measured for a single point in time by using direct-reading colorimetric detector tubes. These measurements are called grab samples.

This measurement involves the use of a pump with detector tubes specific for the contaminant in question, in this case carbon dioxide. Drager and MSA are two of the numerous pump and detector tube systems that are available. To measure in the desirable range for indoor air quality investigations, the Drager, MSA, or equivalent carbon dioxide 0.01% tube which measures in the range of 100 to 3000 parts per million (ppm; 0.01% volume to volume in air is equivalent to 100 ppm in air) should be used. Characteristics of pumps and tubes differ from system to system. Pumps and tubes from different systems should never be mixed. There are tubes that will measure in higher ranges but they will not be sufficiently accurate at the range required for these types of investigations.

U.S.: Approximate cost
Pump ($200 - $300)
Tubes ($20 - $30/box)

Carbon dioxide can also be measured for a single point in time using a continuously measuring infrared instrument. For continuous measurements or measurements to define conditions over a period of time, an infrared instrument can be used with a chart recorder or data logger.

For long term measurements, the instrument should be capable of battery as well as ac operation. Gastech, Metrosonics, Fuji, and Foxboro are among a number of manufacturers that sell instruments capable of detecting carbon dioxide levels between 350 and 3000 ppm. While there is a significant initial investment, if there is a large or multibuilding facility involved, an infrared unit will be more versatile and cost effective than detector tubes.

U.S.: Approximate costs of carbon dioxide monitoring equipment

- Gastech RI-411 ($2,700 + $230 for ac operation)
- Gastech 4776 ($2,600 including chart recorder and ac operation)
- Metrosonics AQ-501 ($5,000 to $6,000 depending on accessories. This unit also measures temperature and relative humidity. It can also accept another sensor input within its data-handling capability.
- Foxboro infrared ($6,000 to $16,000 depending on model and accessories)
- Chart recorder ($700 to $1,000)

- Data logger ($700 to $1,000)

Canada: Approximate cost of carbon dioxide monitoring equipment

- Fuji Model ZPF-5 ($3,800)

All equipment should be calibrated, operated, and maintained in accordance with manufacturers recommendations. This maintenance will help to assure the quality of the measurements.

Other potential contaminants shall be identified and periodically monitored by a qualified industrial hygienist. Monitoring schedules will depend on initial results and building or process modifications. Whenever possible, employee exposure to air contaminants must be kept as low as reasonably achievable. In situations where all available engineering and administrative controls are used, the parameter levels in the previously mentioned table have been set to ensure that actual employee exposure averages never exceed the applicable exposure standard. If contaminant levels, as set by the local and/or country regulatory agency in authority are exceeded, prompt action must be taken to alleviate the situation.

For questions and assistance relating to the purchase and use of equipment, the hiring of industrial hygiene consultants, or for further information contact Area or Corporate Environmental Health and Safety.

APPENDIX D GUIDELINE FOR THE CONTROL OF LEGIONNAIRES' DISEASE BACTERIA IN COOLING SYSTEMS

D.1 PURPOSE

This guideline assists in the establishment of a mechanism to detect, prevent, and control conditions in cooling systems which may cause airborne infectious diseases, including Legionnaires' Disease.

This guideline suggests the establishment of a documented testing and preventive maintenance program for air-conditioning and cooling systems.

These suggestions should be considered minimum guidelines and are to be superseded where more stringent local regulations apply.

D.2 BACKGROUND

D.2.1 COOLING TOWERS AND EVAPORATIVE CONDENSERS

Insufficiently or improperly maintained cooling towers and evaporative condensers from air-conditioning systems have been implicated in the transmission of Legionnaires' Disease.

These air-conditioning systems are potential breeding grounds for naturally occurring bacteria, including Legionnaires' Disease Bacteria (LDB), the bacteria associated with Legionnaires' Disease.

During cooling tower operation, bacteria may potentially be dispersed into the air. It is then possible that nearby air intakes may bring the organisms inside to be distributed by the building heating, ventilation, and air conditioning (HVAC) system.

D.2.2 SUGGESTED COURSE OF ACTION

The most prudent course of action is to keep the cooling systems as clean as practical through documented preventive maintenance procedures.

LDB infestations have been shown to be associated with improperly maintained cooling systems.

No cases have been reported where cooling towers are on a regular well-controlled treatment program.

D.3 GUIDELINE

D.3.1 MONTHLY INSPECTION

Perform regular monthly inspection of mechanical equipment, the fill, and both hot and cold water basins (sumps) to ensure they are well maintained, clean, and in a good state of repair.

D.3.2 DRAINING AND CLEANING

Draining and/or cleaning of wetted surfaces and areas of alternate wetting and drying at least quarterly in order to prevent the accumulation of dirt, scale, slime, and algae in which microorganisms (such as amoeba, fungi, LDB, and other bacteria) may grow.

In many instances, complete draining is not practical because it might involve a complete system shutdown. A common practice is to use a scrubbing tool, such as a stiff broom, to clean exposed and/or reachable surfaces. Accumulated matter is then drained from the sump. Suspended particles are reduced by bleed-off.

D.3.3 CHEMICAL BIOCIDE TREATMENT

Chemical treatment provides a method of effective control of the cooling water for microorganisms, scale, and corrosion control.

The chemical treatment program should be coordinated with other maintenance activities, such as cooling tower cleaning and water bleed (blowdown).

Depending on the situation, continuous feed of biocides may be preferred to slug dosing. Continuous feed provides the cooling tower with a continuous and consistent concentration of biocides, while slug dosing does not.

Continuous feed of biocides needs to be used with caution. The cooling tower bleed-off may have a level of toxicity, which must be within acceptable local water effluent discharge levels.

The proper use and timing of slug dosing and bleed-off can minimize water treatment concerns and still offer the proper quality control.

Two alternative biocides of different composition are needed to prevent evolution of biocide resistant bacterial strains.

D.3.4 OZONATION

May be a viable alternative to chemical treatment in cooling tower operation.

The process uses less make-up water than chemical treatment.

There is no chemical containing blowdown. This treatment is especially important where there are water discharge restrictions.

The volume of the blowdown can be reduced significantly or it can be potentially completely eliminated.

Tests have shown almost 100% biological contaminant control. The operation of the system has also been shown to be much cleaner. Scale, corrosion, and slime are reduced.

An ozonation system requires the involvement of sufficiently skilled operational and maintenance personnel.

Any discussion on the potential application of this technique should include Corporate Design and Facilities, and/or Area or Corporate Environmental Health and Safety. Potential issues that will need to be considered involve cost justification, operating costs, equipment modification, and possibly environmental permitting requirements.

D.3.5 ANALYSIS OF MICROBIOLOGIC CONTENT OF COOLING WATER

This analysis should be performed at least monthly to ensure that the total bacterial count is kept under optimal control. If higher than acceptable levels of bacteria are detected, the frequency of testing and cleaning should be increased to weekly until control has been established.

A cooling tower with a total bacterial count (plate count) of less than 500,000 colony forming organisms per milliliter of water is generally considered to be under adequate control. Facilities should try to achieve this level of control unless local requirements are more stringent.

Monitoring the total bacterial count in the cooling system water is a useful guide to the general effectiveness of the biocide treatment program and to the possible need for modification.

For determination of cooling system bacterial counts, advice of a water treatment specialist should be obtained. The consultant can test and recommend effective control methods.

D.3.6 PROCESS DOCUMENTATION

Systematic documentation of operating and maintenance functions is required.

A permanent record should be established and maintained including the date and time each chemical was used, the brand of the chemical, the volume or weight added, and the effectiveness of the treatment method including all analytical and biological test results.

This information should be kept and maintained, even if the service is contracted.

D.3.7 LEGIONNAIRES' DISEASE BACTERIA SAMPLING AND CULTURING RECOMMENDATIONS

Routine culturing or sampling is not recommended for LDB without a well-defined outbreak of the disease.

There is difficulty in culturing and interpretation of the data which may lead to improper conclusions being drawn and raising unnecessary concerns.

It is more important to ensure a cleaning and maintenance program for the cooling towers and associated equipment be in place.

D.3.8 EMPLOYEE PROTECTION

All employees performing work with biocides and cleaning cooling systems must be protected from possible chemical or biological hazards.

Where necessary, appropriate engineering controls (ventilation), training (hazard awareness), and personal protective equipment (gloves, face shield, respirator) must be incorporated into the maintenance program.

Employees involved in biocide handling and cooling system cleaning should be monitored for potential exposure and health effects from biological and chemical hazards.

APPENDIX E GENERAL INDOOR AIR QUALITY SURVEY QUESTIONNAIRES

The following are examples of two types of survey questionnaires that can be used to investigate issues potentially involving building-related complaints. They are included as examples and can be modified based on their applicability to the particular building and/or situation.

INFORMATION FOR THE INVESTIGATION OF INDOOR AIR QUALITY COMPLAINTS

INVESTIGATOR: _____

FACILITY: _____

DATE: _____

1. Specific nature of the complaints, odors, headaches, irritation, and so forth

   _____

   _____

   _____

   What locations report the worst or most complaints?

   _____

   _____

   Number of people complaining? _____ Total people in complaint area(s)? _____

   What is the history of the complaints? Was there a triggering incident? Is there any apparent pattern (time of day or week, seasonal, and so forth)?

   _____

   _____

   _____

   How long has the group been in the building? _____

   Is the building new, old, or renovated? _____

   Who manages the building? _____

2. List any activities using chemicals of any type in the areas of concern.

   _____

   _____

   _____

   Any recent inside or outside use of pesticides, paints, sealants, and so forth?

   _____

   _____

   _____

3. Describe the heating, cooling, and ventilation system in these areas. Is there a central heating, ventilation, and air cooling (HVAC) unit and if so where is it located?

Describe the type, general location, and dimensions of the local air supply and return air vents.

Are there separate air exhaust units? Are they operable and used?

Does the mechanical ventilation system have an outside air intake? If so, what is the approximate percentage of outside air currently being supplied, and is it adjustable?

If there are modulating controls, what are the settings and percentages?

Can the windows be opened? _____

Heating system type? Gas _____ Oil _____ Electric _____ Other _____

Is the ventilation system regularly maintained? _____ If so, by whom?

_____

When were the filters last changed or cleaned? _____

When was the system last thoroughly checked for proper operation and by whom?

How is the ventilation set and operated? Is the system on a pneumatically controlled computerized system? _____ Is the system on a timer? _____ If manual operation only, is control of the thermostats restricted? _____

What hours is the system completely on, and to what extent is the system shut down overnight and weekends?

What are the normal temperature settings for the different times of the day and week?

When the system is on, are the fans on continuously or on only when there is temperature demand (automatic)?

Humidity control?

None? _____ Built into the ventilation system? _____
Provided by independent units? _____ Other?_____

Perceived or actual relative humidity range?

What are the best guesses as to the cause of the complaints and as to what can be done to improve occupant health and comfort?

GENERAL SURVEY QUESTIONS FOR THE INVESTIGATION OF INDOOR AIR QUALITY COMPLAINTS

INVESTIGATOR: _____

FACILITY: _____

DATE: _____

1. Are you aware of any issues that may be occurring as a result of environmental factors at work? Yes _____ No _____

   _____

   _____

   _____

2. What are some of the issues you have heard about?

   _____

   _____

   _____

   _____

3. Have you experienced any of these problems or symptoms? Yes _____ No _____
4. What problems or symptoms have you experienced? (Check all appropriate symptoms as first described by the person being interviewed).

   Headache _____ Dizziness _____

   Drowsiness _____ Light-headedness _____

   Sore throat _____ General feeling of illness _____

   Other _____

   _____

5. When did you first notice these problems occurring?

   After moving to your present location? _____

   Before moving to your present location? _____

   For the past _____ days/weeks/months?

   Other _____

   _____

6. Does anything make these problems better?
   Leaving your work area? _____
   Leaving the building? _____
   Other? _____
7. Does anything make these problems worse?
   Fatigue? _____ Stress? _____
   Time of day? _____ If so, what time? _____
   Particular day of the week? _____ What day? _____
   Being in a particular part of the building? _____
   What part of the building? _____
   Being in a particular part of a floor? _____
   What part of the floor? _____
8. Have you ever experienced problems like this before? Yes _____ No _____
   If yes, please explain.

   _____

   _____

   _____
9. What do you think may be causing these problems?

   _____

   _____

   _____
10. Have you sought medical treatment for these problems? Yes _____ No _____
11. Do you intend to seek medical treatment? Yes _____ No _____
12. Have you ever been treated for these problems in the past? Yes _____ No _____

13. Can you describe the environment in which you work?

    Seating arrangement: _____

    Ventilation: OK _____ Stuffy _____ Environmental tobacco smoke _____

    Drafts _____ Other

    _____

    _____

    Temperature: OK _____ Too hot _____ Too cold _____

    Humidity: OK _____ Too hot _____ Too cold _____

    Stressful? Yes _____ No _____ If yes, what do you think may be causing the stress?

    _____

    _____

    _____

14. What do you feel should be done about these problems?

    _____

    _____

    _____

15. Do you smoke cigarettes or cigars? Yes _____ No _____
16. Do you eat at your desk? Yes _____ No _____
17. Is there anything else you would like to say about these problems?

    _____

    _____

    _____

APPENDIX F REFERENCED DOCUMENTS

F.1 Other Digital Documents

Document Number	Document Title
EF-A0931-50	*Design and Development of the Work Environment*

F.2 Other Documents

Document Number	Document Title
ASHRAE 62-1987	*Ventilation for Acceptable Indoor Air Quality*

F.3 Ordering Information

Following are the sources for documents not available from Standards and Methods Control.

- Manager of Corporate Design and Facilities
  MSO2-3/G19
- American Society of Heating, Refrigerating and Air-Conditioning Engineers
  1791 Tullie Circle, NE
  Atlanta GA 30329

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